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Coastal and ocean flow modelling with equal order finite elements

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Finite element methods offer a lot of practical advantages in engineering hydraulics and geophysical fluid mechanics where one often has to deal with complex geometries of irregular shape. Unstructured finite element meshes are ideally suited for these situations with arbitrary topography. Moreover, in an engineering environment, different alternative hydraulic designs may have to be investigated consecutively for which quick modification of the basic computational mesh is of practical advantage. Unstructured models offer the possibility to adjust or refine the basic mesh locally without too much distortion elsewhere.

As a prerequisite the flow model should be able to deal efficiently with the sparse matrices resulting from the finite element discretization. Equal order linear elements, where the velocity components and the pressure are approximated in the same space of piecewise linear functions, are particularly useful in this respect. The matrices to be assembled at the element level have a simple structure and, what is even more important, only one sparsity pattern for both the velocity and the pressure needs to be dealt with. Unfortunately, equal order discretizations are generally unstable and stabilizing terms have to be added to the equations. This may soon become rather

cumbersome while it is also difficult to achieve optimal model behaviour for different flow situations.

The presentation will illustrate some of these issues related to stabilization and present a new velocity-pressure discretization based on equal order elements. Some computational examples of 3-dimensional non-hydrostatic flows and 2-dimensional shallow water flows typically occurring in a coastal environment, including the effects of density differences and Coriolis, will be shown to demonstrate the new approach.